

WHAT IS CLAIMED:

1. A photocatalytic material, which exhibits photocatalytic activity when exposed to light comprising a wavelength in a region of visible light, said material comprising Ti-O-N containing nitrogen in lattices of titanium oxide crystal.

5           2. The photocatalytic material of Claim 1, wherein a nitrogen atom of said Ti-O-N is contained in lattices of said titanium oxide crystal by at least one process comprising substituting a nitrogen atom for an oxygen site of said titanium oxide crystal, doping a nitrogen atom at an interstitial site of lattices of said titanium oxide crystal, or doping a nitrogen atom between grain boundaries of said titanium oxide crystal.

3. The photocatalytic material of Claim 1, wherein a chemical bond exists between a nitrogen atom present in the titanium oxide crystal and a titanium atom.

4. The photocatalytic material of Claim 3, wherein the nitrogen atom is substituted for an oxygen site of the titanium oxide crystal.

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15           5. The photocatalytic material of Claim 3, wherein a N1s shell bond energy spectrum of the photocatalytic material exhibits at least one peak in about the 400eV or less region, when measured using X-ray photoemission spectroscopy.

6. The photocatalytic material of Claim 3, wherein a N1s shell bond energy spectrum of the photocatalytic material exhibits at least one peak in the region between about 396eV and 398eV, when measured using X-ray photoemission spectroscopy.

20           7. The photocatalytic material of Claim 3, which has an impurity level caused by substituting a nitrogen atom for an oxygen site of titanium oxide between a band gap of a valence band and a conduction band of titanium oxide.

8. The photocatalytic material of Claim 3, wherein nitrogen content X expressed in atomic % is  $0 < X < 13\%$ .

9. The photocatalytic material of Claim 3, wherein atomic % values Y, Z, and X for titanium, oxygen, and nitrogen satisfy the expression,  $0.4 < Y/(X + Z) < 0.6$ .

10. The photocatalytic material of Claim 3, wherein the X-ray photoemission spectroscopy spectrum exhibits a peak derived from ammonium salt.

11. The photocatalytic material of Claim 3, wherein a crystal face of a photocatalytic article or a film is oriented along the C axis direction on its surface.

12. The photocatalytic material of Claim 1, having the empirical formula  $Ti_{33.9}O_{64.7}N_{1.4}$ .

13. The photocatalytic material of Claim 1, having the empirical formula  $Ti_{34}O_{65}N_1$ .

14. The photocatalytic material of Claim 1, having the empirical formula  $Ti_{31}O_{67}N_2$ .

15. A photocatalyst, which exhibits photocatalytic activity when exposed to light with a wavelength in a region of visible light, said photocatalyst comprising Ti-O-N containing nitrogen in lattices of titanium oxide crystal, wherein a chemical bond exists between the nitrogen atom present in the titanium oxide crystal and a titanium atom and wherein an external surface of the photocatalyst comprises titanium oxide containing no nitrogen.

16. A photocatalyst, comprising as an inner component at least one of titanium oxide, silica, alumina, fluororesin, or those containing nitrogen, and as an external component on a whole or some portion of an external surface, the photocatalytic material of Claim 3.

17. A photocatalyst, wherein at least one of titanium oxide, silica, alumina, fluororesin or those containing nitrogen is mixed with the photocatalytic material of Claim 3.

18. A photocatalytic article, comprising the photocatalytic material to Claim 3, wherein a surface of the photocatalytic material comprises a ceramic with a lower

photocatalytic activity than said photocatalytic material, which ceramic is carried in an island, needle, or mesh form.

19. The photocatalytic article of Claim 18, wherein the ceramic with a lower photocatalytic activity than said photocatalyst is at least one selected from the group consisting of alumina, silica, zirconia, magnesia, calcia, calcium phosphate, amorphous titanium oxide, and fluoro-resin.

20. The photocatalytic article of Claim 18, wherein the ceramic with a lower photocatalytic activity than said photocatalytic material is at least one selected from alumina, silica, zirconia, magnesia, calcia, potassium phosphate, amorphous titanium oxide, and fluoro-resin which contains nitrogen.

21. The photocatalytic article of Claim 18, wherein the ceramic is in an island form.

22. The photocatalytic article of Claim 18, wherein the ceramic is in a needle form.

23. The photocatalytic article of Claim 18, wherein the ceramic is in a mesh form.

24. A method of manufacturing a photocatalytic article, which comprises forming a thin film of the photocatalytic material of Claim 3, on a substrate by sputtering at least one of titanium-oxynitride, titanium oxide, titanium nitride, or titanium metal as a target material in an atmosphere containing nitrogen gas.

25. A method of manufacturing a photocatalytic article, which comprises forming a thin film of the photocatalytic material of Claim 3, on a substrate by vaporizing or ion plating at least one of titanium-oxynitride, titanium oxide, titanium nitride, or titanium metal as a target material in an atmosphere containing nitrogen gas.

26. A method of manufacturing a photocatalytic article, which comprises forming the photocatalytic material of Claim 3, by heat-treating titanium oxide or hydrated titanium oxide

in an atmosphere containing ammonia gas, nitrogen gas, or mixture of nitrogen and hydrogen gases.

27. A method of manufacturing a photocatalytic article, which comprises forming the photocatalytic material of Claim 3, by heat-treating a titanium alkoxide solution in an atmosphere containing ammonia gas, nitrogen gas, or mixture of nitrogen and hydrogen gases.

28. A method of manufacturing a photocatalytic article, which comprises forming the photocatalytic material of Claim 3, by treating titanium oxide in plasma containing nitrogen atom.

29. A method of manufacturing a photocatalytic material, which comprises forming the photocatalytic material of Claim 3, by implanting nitrogen atom in titanium oxide by ion-implantation.

30. A method of manufacturing a photocatalytic article, which comprises forming the photocatalytic material of Claim 3, by vacuum evaporating at least one of titanium-oxynitride, titanium oxide, titanium nitride, and metal titanium used as an evaporating material in an atmosphere containing nitrogen gas, and then transferring it to a different vacuum vessel using differential pressure.

31. An emulsion combustion method of manufacturing the photocatalytic material of Claim 3, comprising spray combusting an emulsion in the atmosphere such that ions or molecules containing nitrogen elements other than nitrate ion are present in an aqueous solution or suspension of metallic salts which is an aqueous phase in an emulsion, wherein an amount of oxygen introduced into a reactor is less than that required for producing the oxides of metallic ions or metal compounds which are in most stable forms in the air, keeping the sufficient amount of oxygen to burn the oil and surfactant completely.

32. A method of manufacturing the photocatalytic material of Claim 3, comprising, in an emulsion combustion method, spray combusting an emulsion in the atmosphere in which a

nitrogen containing gas, excluding nitrogen gas, is contained in an aqueous solution or suspension of metallic salts which is the aqueous phase in an emulsion and in which the amount of oxygen introduced into a reactor is less than that required for complete oxidation.

33. A method of manufacturing the photocatalytic of Claim 3, which comprises mixing titanium oxide and titanium nitride are mixed, to form a mixture and heat-treating the mixture at a temperature between about 400 and 700°C.

34. A method of manufacturing the photocatalytic material of Claim 3, which comprises heat-treating or plasma-treating titanium nitride or titanium-oxynitride in an oxidation atmosphere containing oxygen, ozone, a water molecule, or a hydroxyl group.

35. A method of decomposing an organic compound, which comprises contacting the organic compound with the photocatalytic material of Claim 1, in the presence of light having a wave length ( $\lambda$ ) of greater than 200 $\mu$ m.

36. The method of Claim 35, wherein said light has an intensity of about 5 mW/cm<sup>2</sup> or greater.

37. The method of Claim 35, wherein said photocatalytic material is present in a form of a film and said organic compound is decomposed at a surface of said film.

38. The method of Claim 35, wherein said light has a wavelength of greater than 400 $\mu$ m.

39. The method of Claim 38, wherein said light has a wavelength of up to about 500 $\mu$ m.

40. The method of Claim 35, wherein said organic compound decomposed is an organic solvent.

41. The method of Claim 35, wherein said organic compound decomposed is an agricultural chemical.

42. The method of Claim 35, which is effected indoors.

43. A method of decomposing air pollutants, comprising contacting said air pollutants with the photocatalytic material of Claim 1, in the presence of light having a wavelength ( $\lambda$ ) of greater than 200 $\mu$ m.

44. The method of Claim 43, wherein said air pollutants comprise nitrogen oxides.

45. The method of Claim 44, wherein light has an intensity of about 5 mW/cm<sup>2</sup> or greater.

46. The method of Claim 43, wherein said photocatalytic material is present in a form of a film, and said organic compound is decomposed at a surface of said film.

47. The method of claim 43, wherein said light has a wavelength of greater than 400 $\mu$ m.

48. The method of Claim 47, wherein said light has a wavelength of up to about 500 $\mu$ m.

49. A photocatalyst, comprising the photocatalytic material of Claim 1, in a carrier.

50. The photocatalyst of Claim 49, wherein said carrier is glass.

51. The photocatalyst of Claim 49, wherein said carrier is zeolite.

52. The photocatalyst of Claim 49, wherein said carrier is activated carbon.